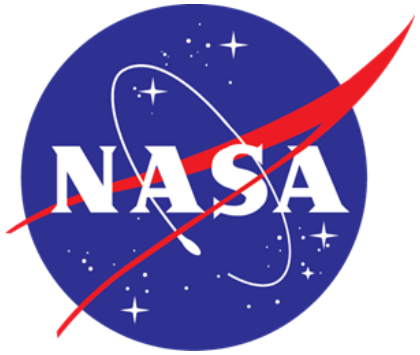


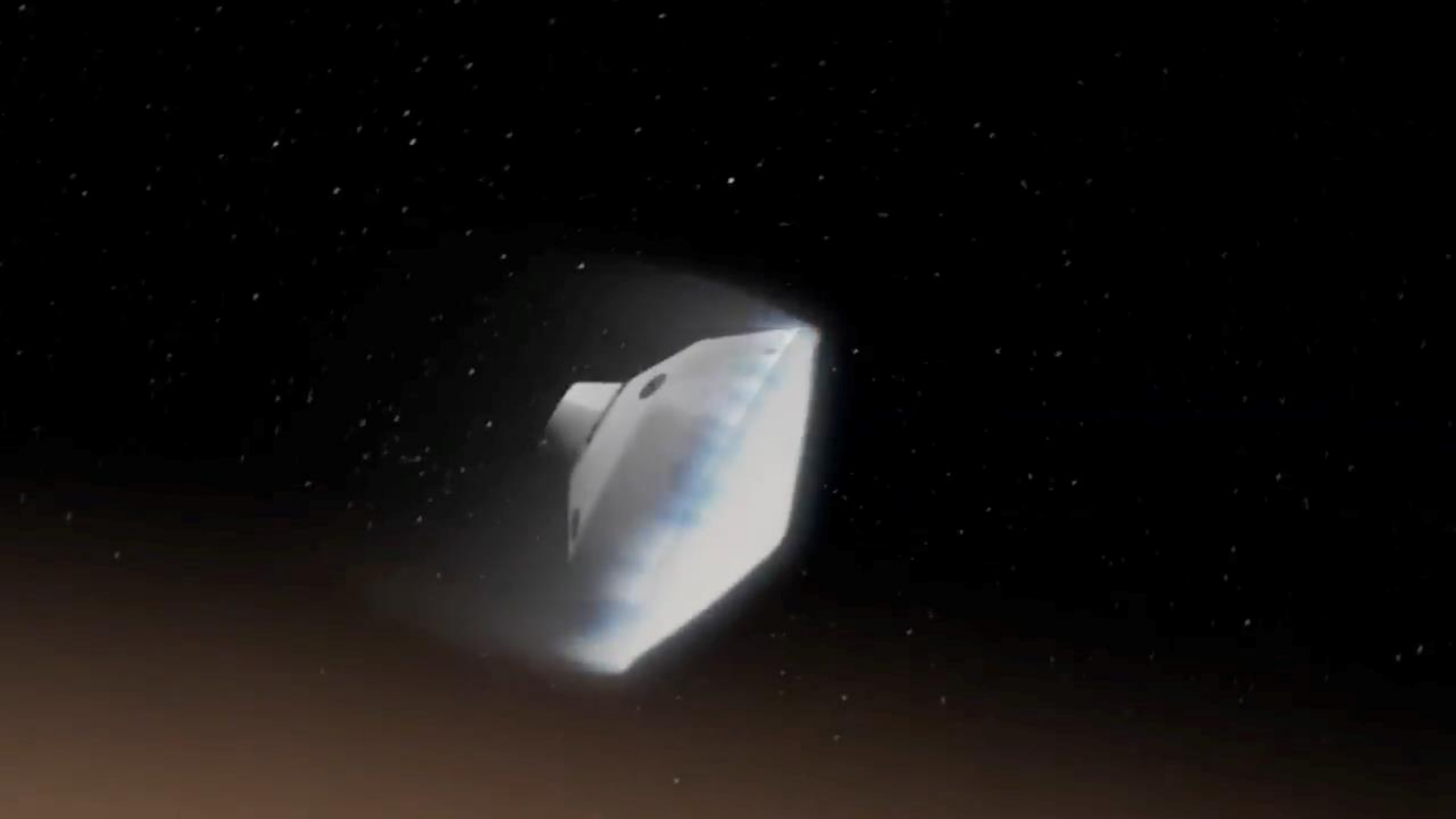
Bite of Science
Exploring Space

Alphan Altinok, Ph.D.
Machine Learning and Instrument Autonomy
Jet Propulsion Laboratory, California Institute of Technology.

Nov. 26, 2011

60,000 mph

13,000 mph



Aug. 6, 2012
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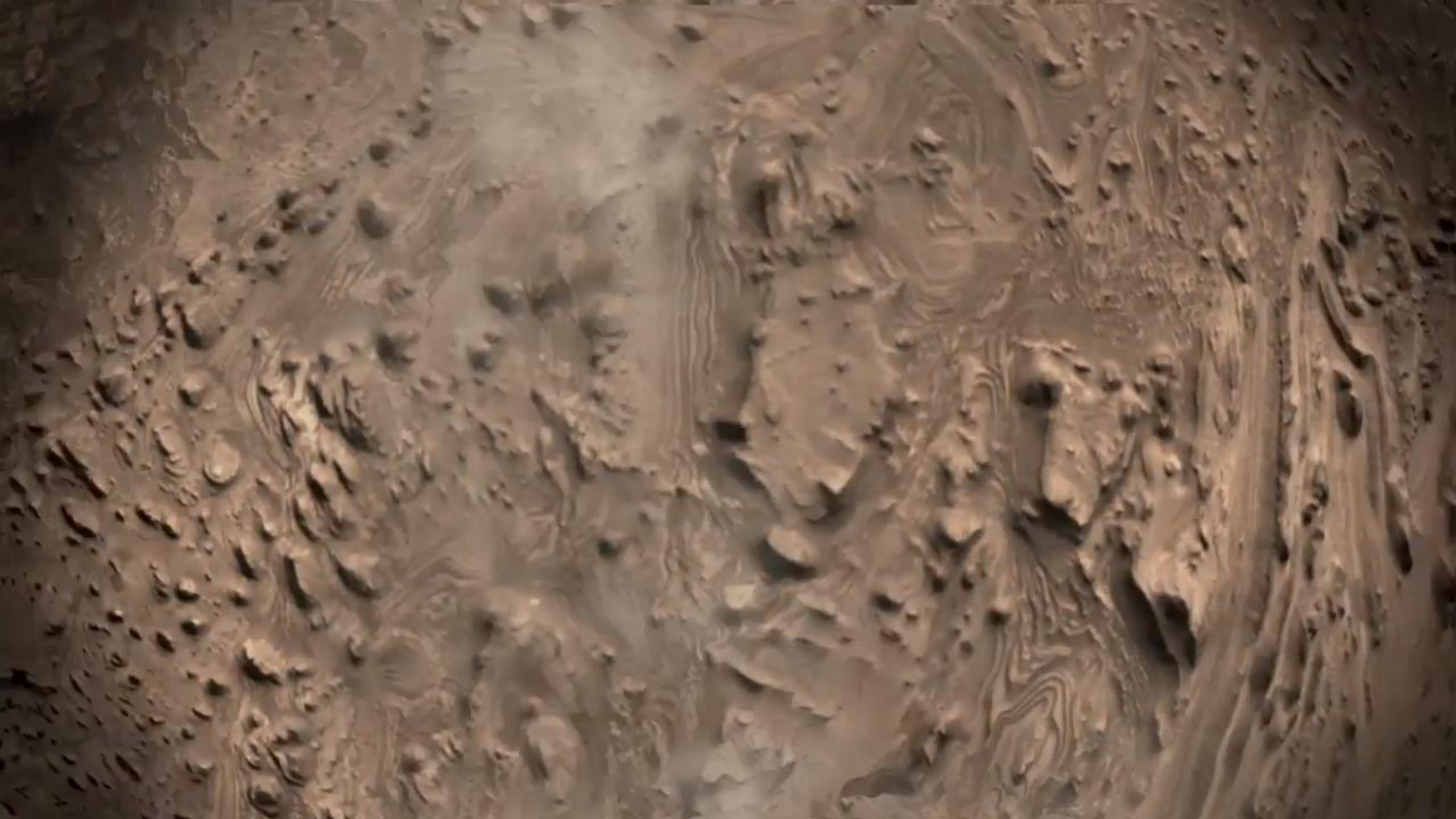
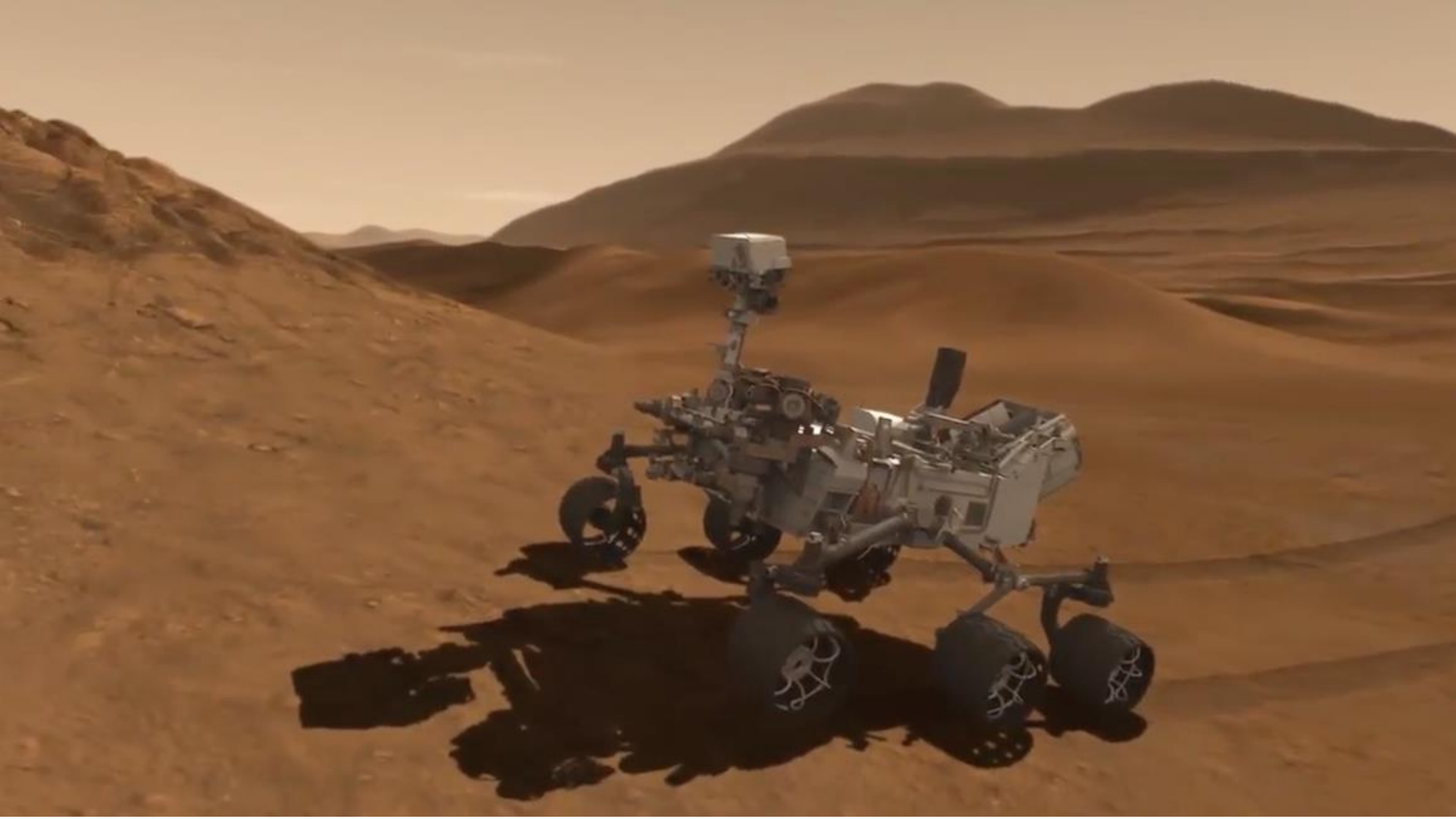
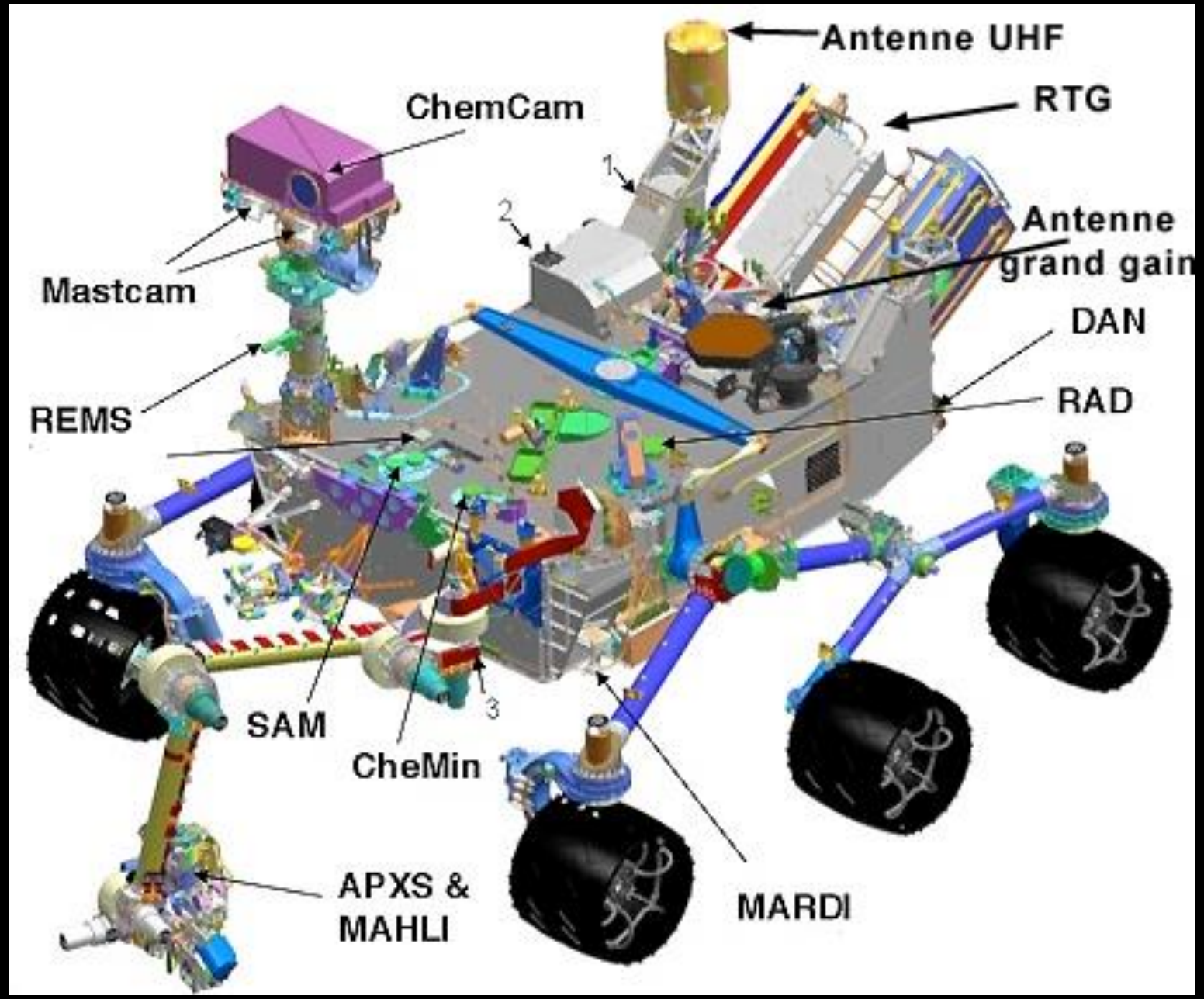
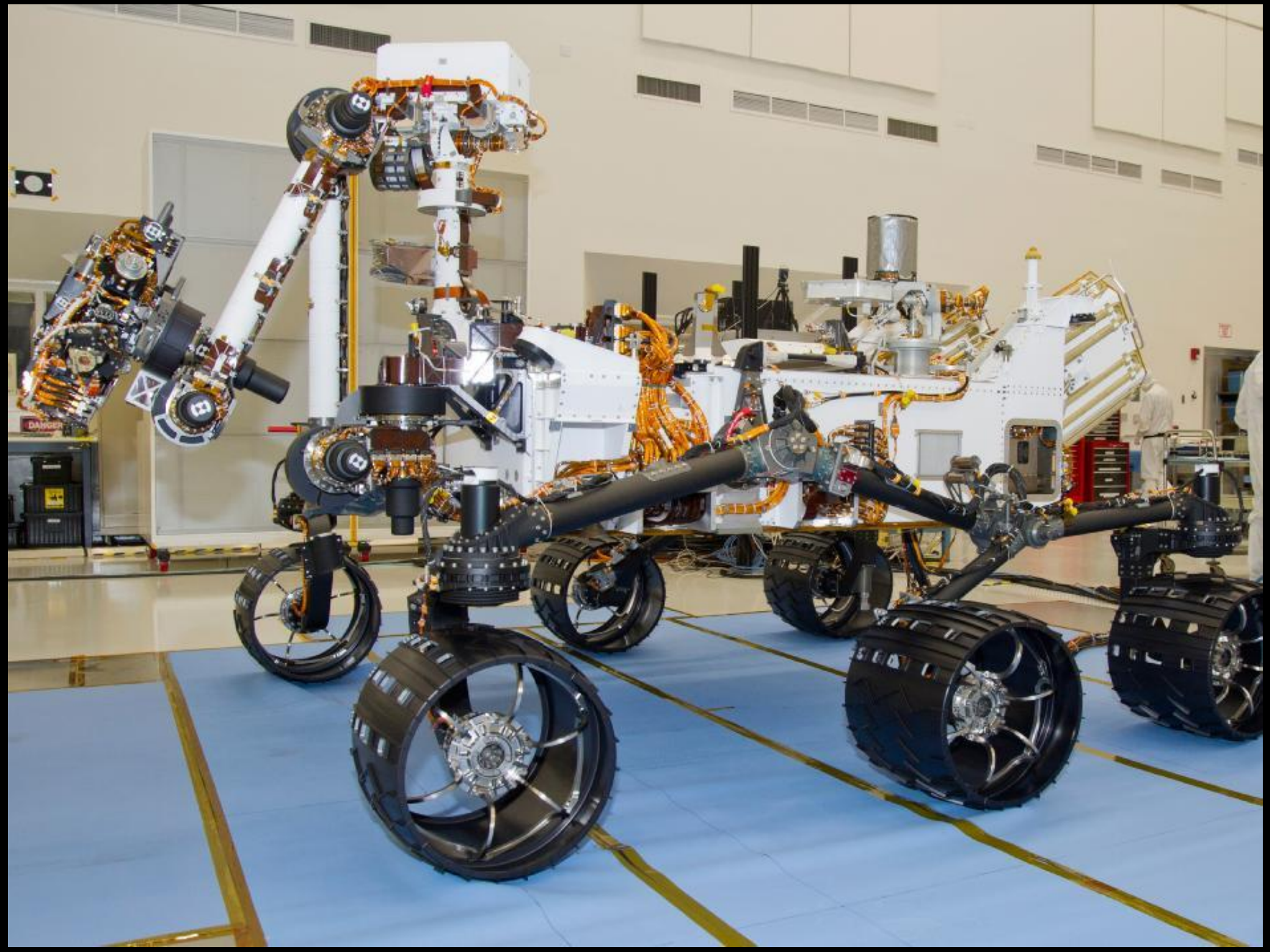


+ 13 min 48 sec

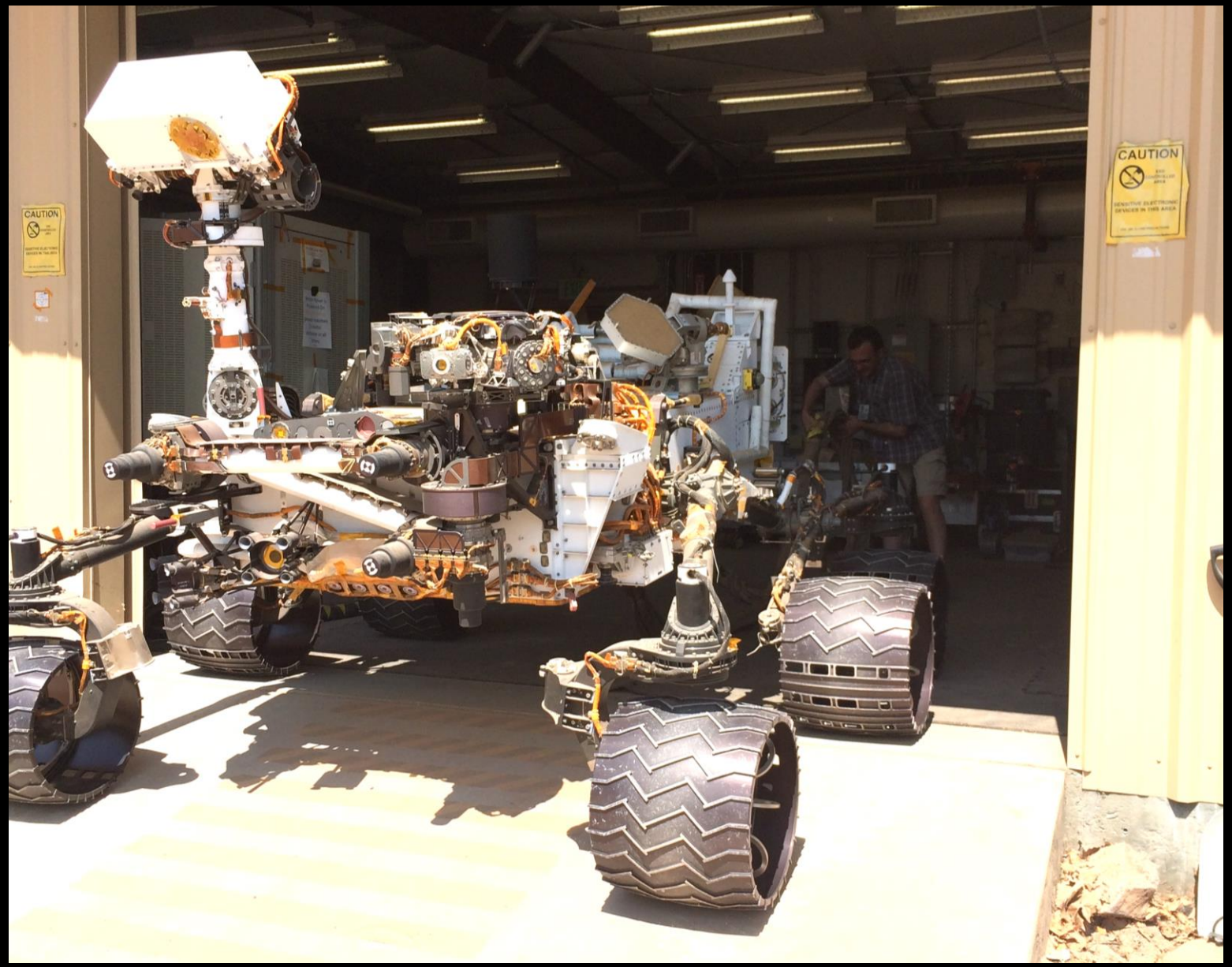

NASA
Jet Propulsion Laboratory




Antenne UHF
RTG
ChemCam
1
2
Antenne
grand gain
Mastcam
DAN
REMS
RAD
SAM
3
CheMin
APXS &
MAHLI
MARDI




HERE

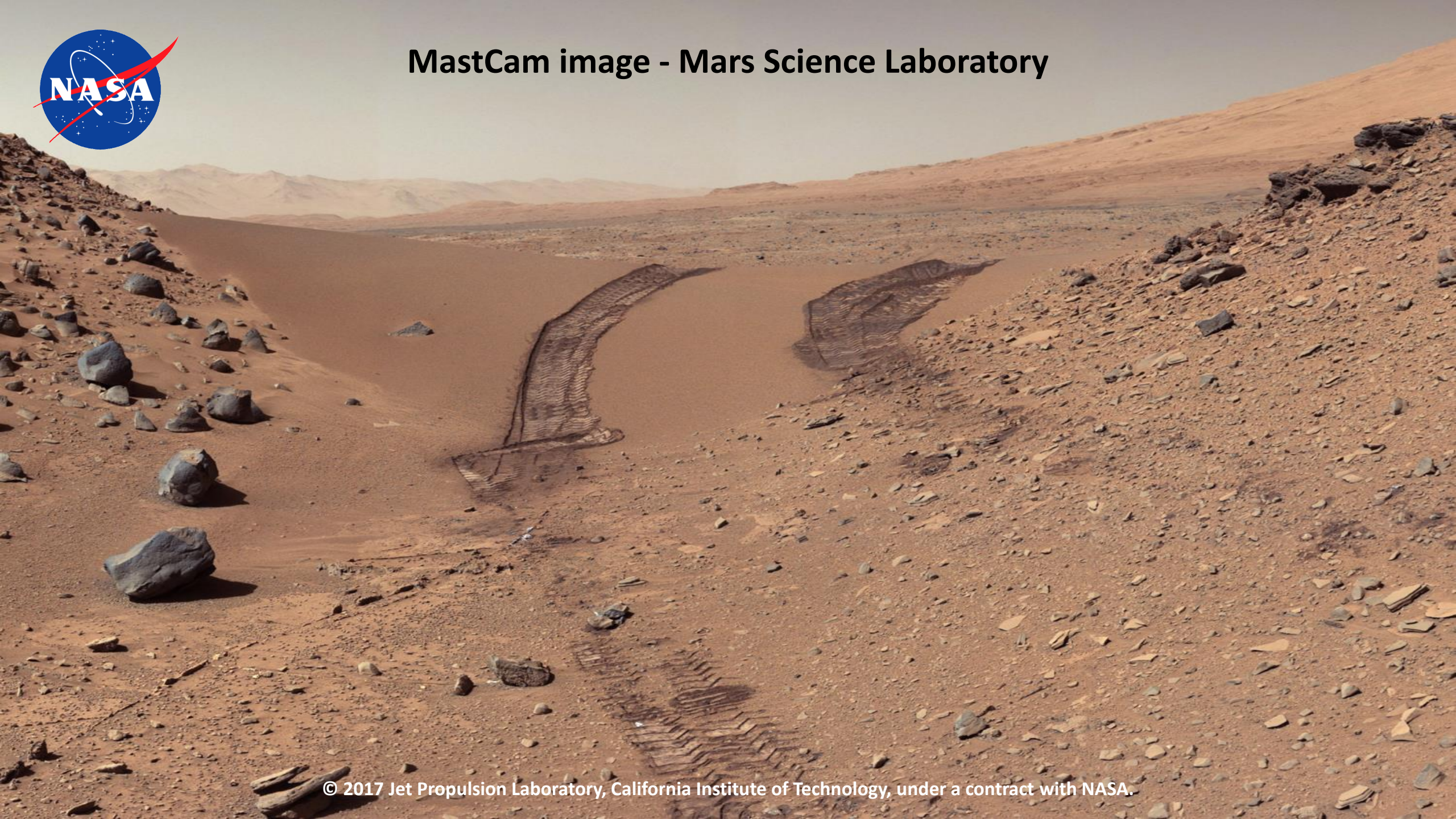

CAUTION
CAUTION

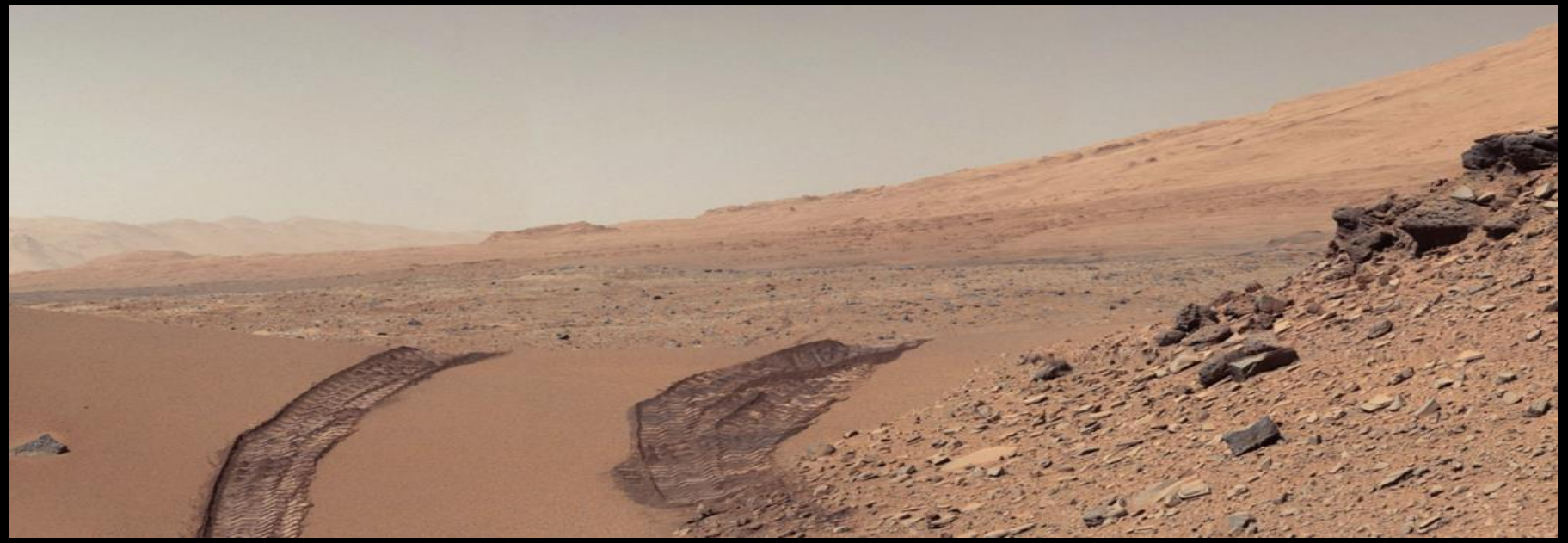

EXIT
FORKS

Mars

Geology
Meteorology
Biology

MastCam image - Mars Science Laboratory



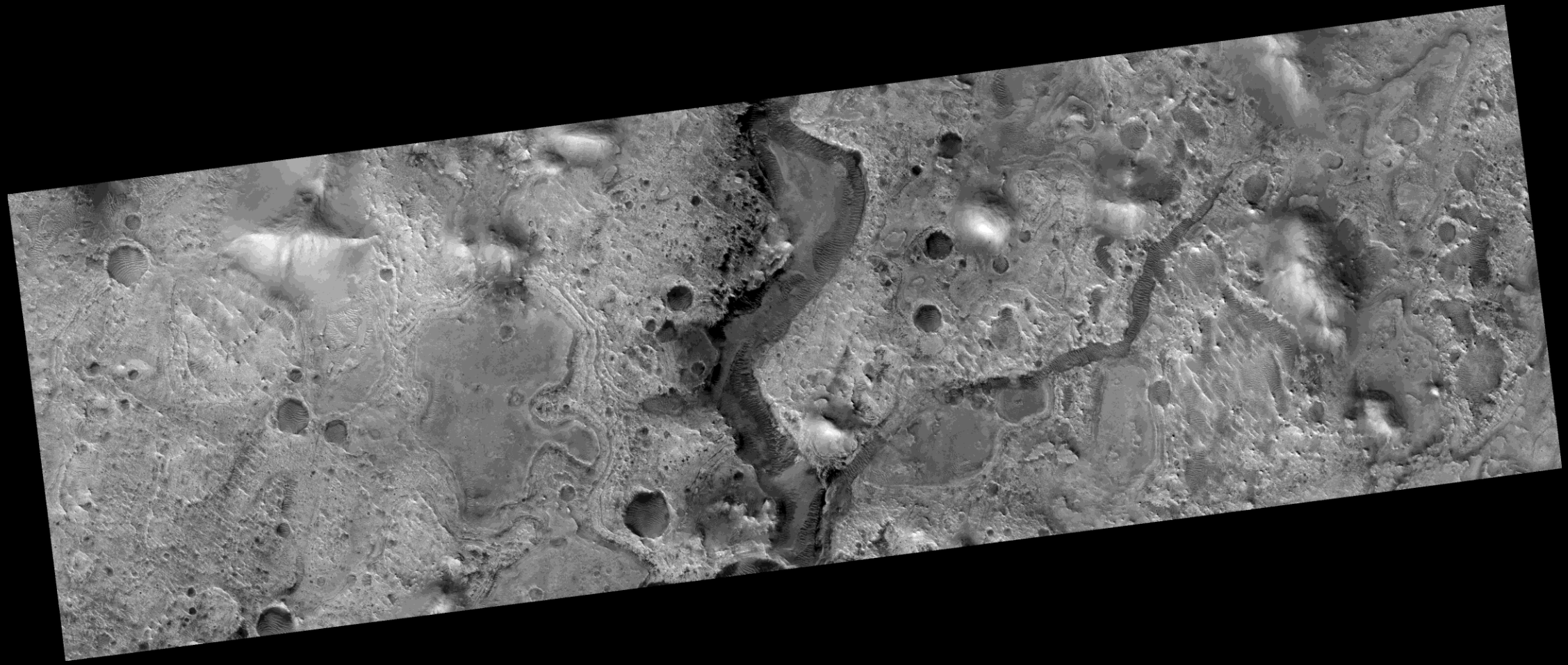


What do we learn

What would you think ?

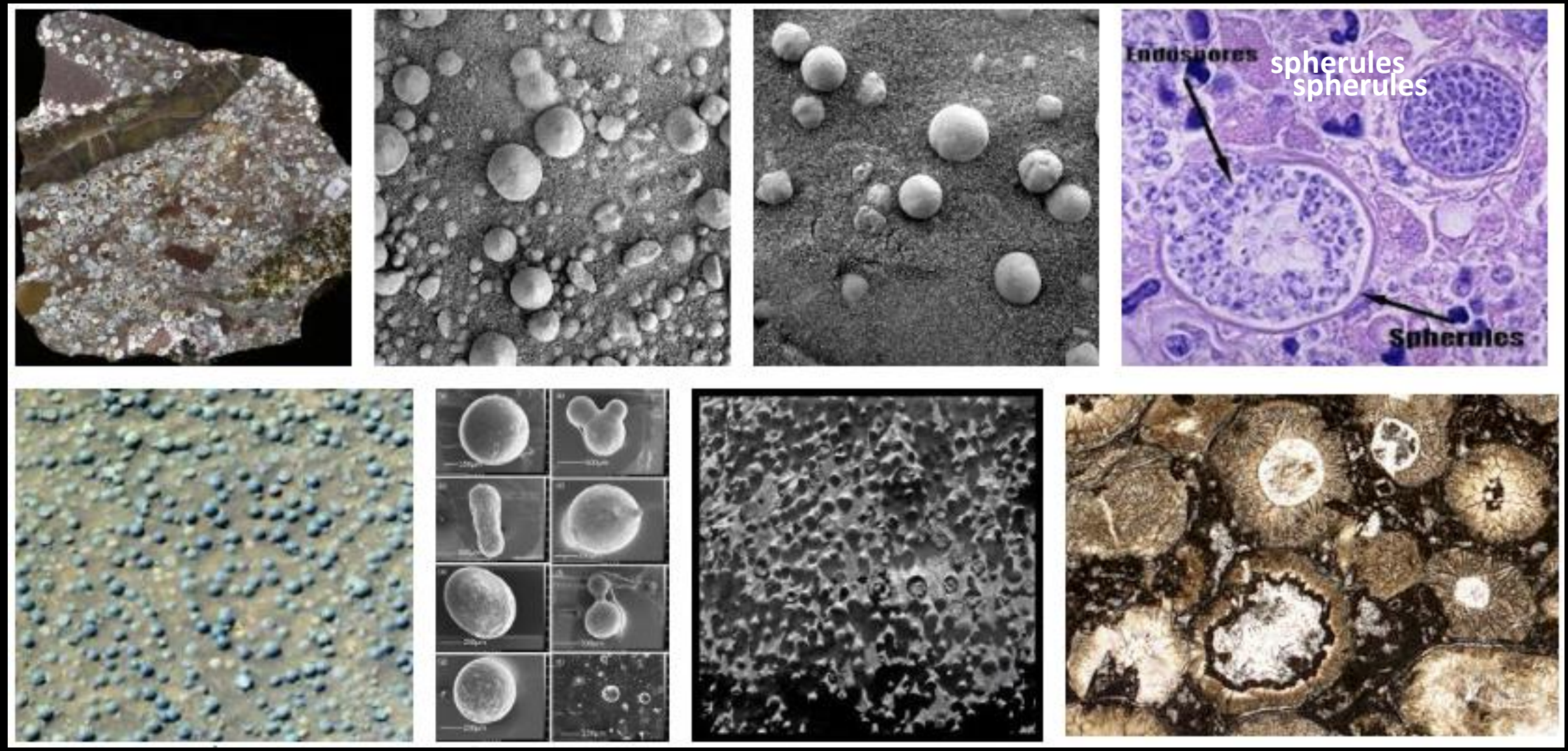
https://www.nasa.gov/feature/jpl/mars-rover-curiosity-examines-possible-mud-cracks

What would you think ?

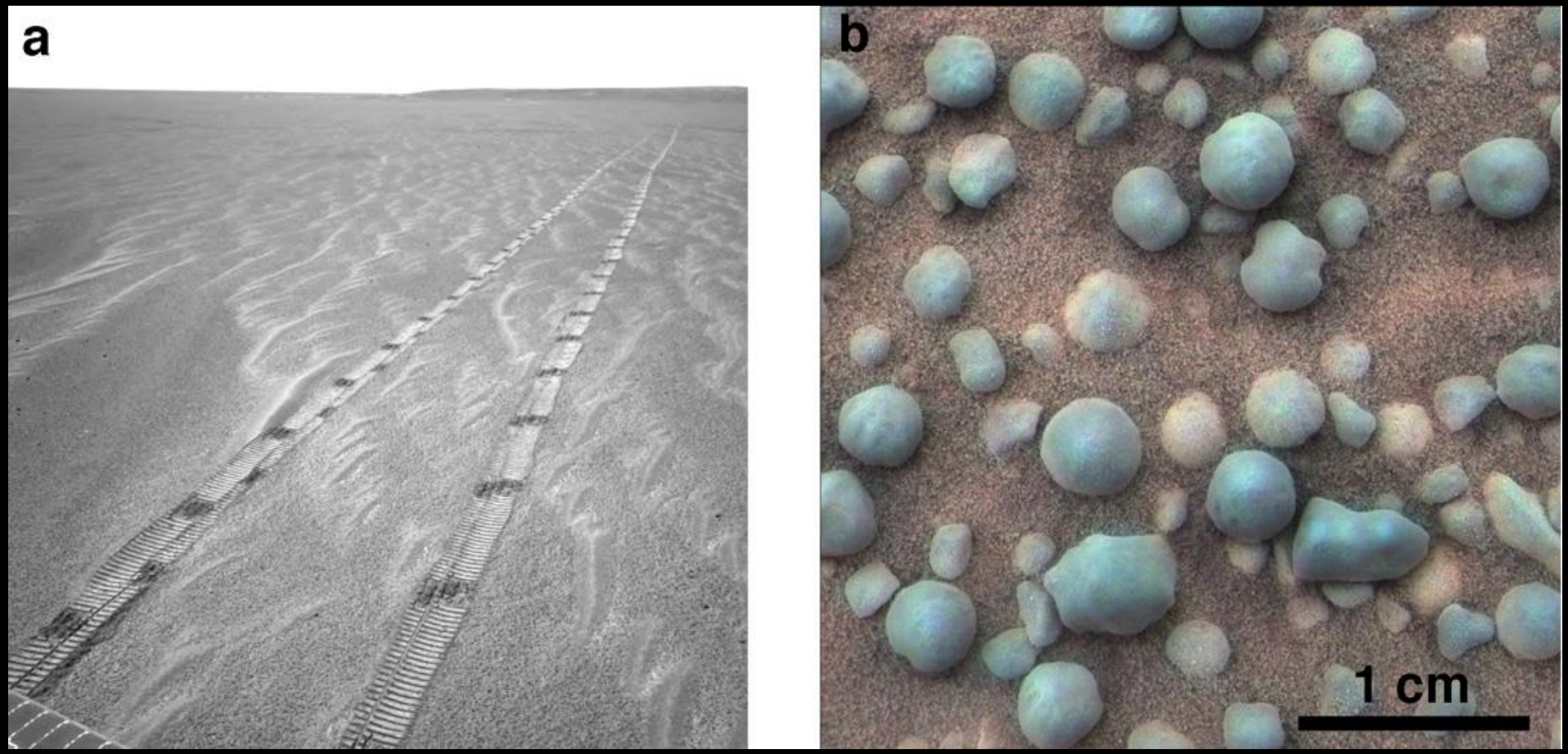


https://hirise.lpl.arizona.edu/ESP_026359_1990

https://hirise.lpl.arizona.edu/ESP_026359_1990

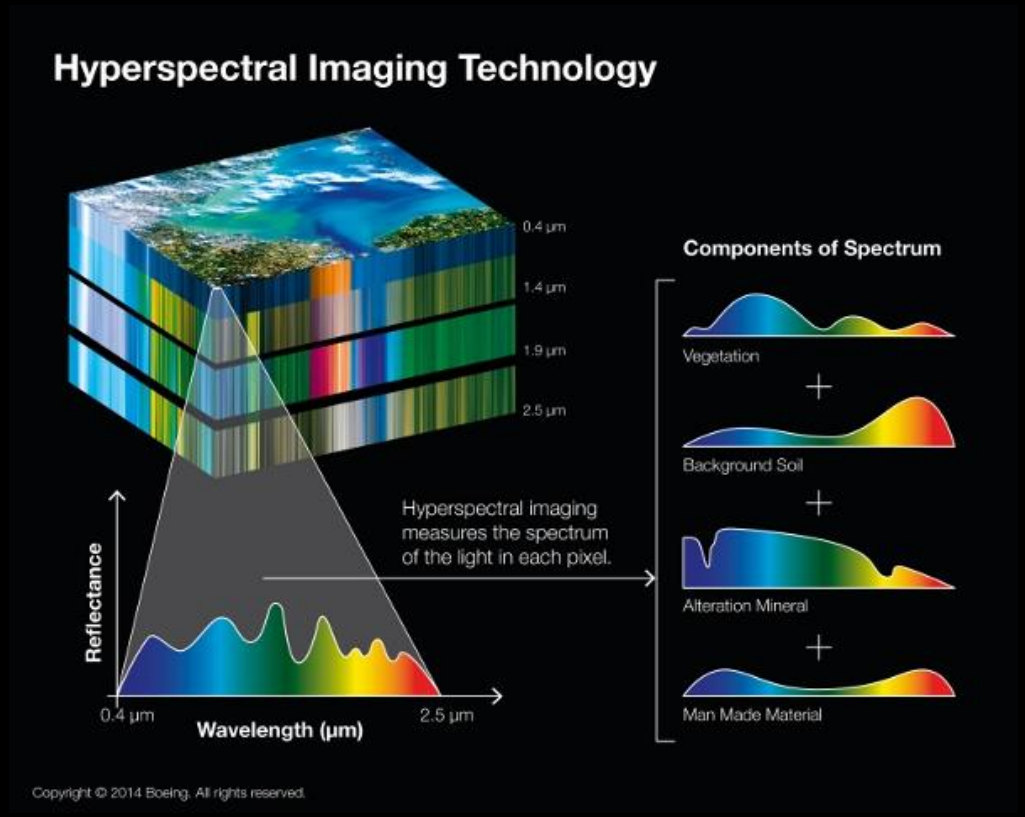


What are these ?



(a) Opportunity Navcam Sol 359 image illustrating the surface morphology along the plains of Meridiani Planum. Rover tracks can be seen in the soils. (b) Microscopic Imager image merged with Pancam false-color of the typical grains that compose the soils seen along the plains at the Meridiani Planum landing site. The larger grains average 1.6 mm in diameter and most are the hematite-rich spherules (blue color) that form a lag on the surface. The finer grains that are<100 mm in size are dust and basaltic sand.

How do we look for life?



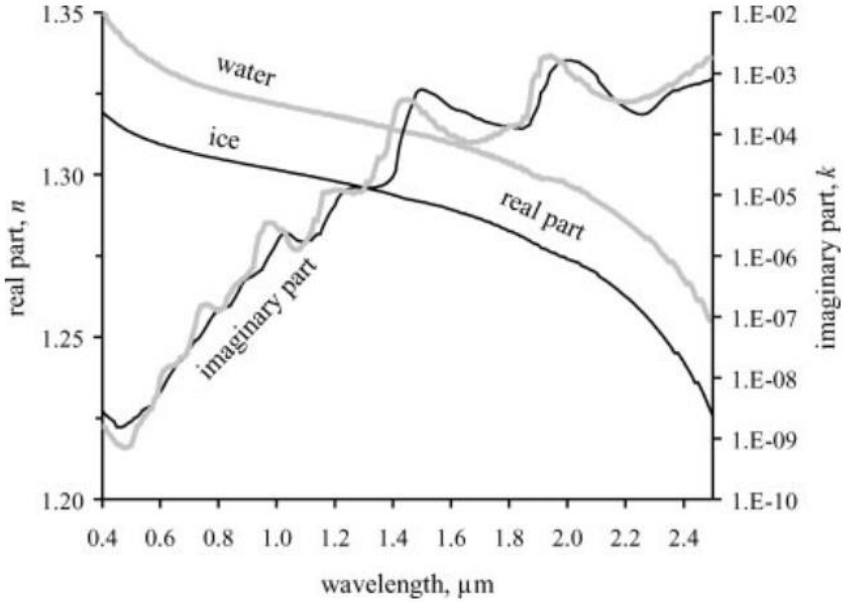


Figure 1 Complex refractive indices of ice and water (Wiscombe 1994, 1995).

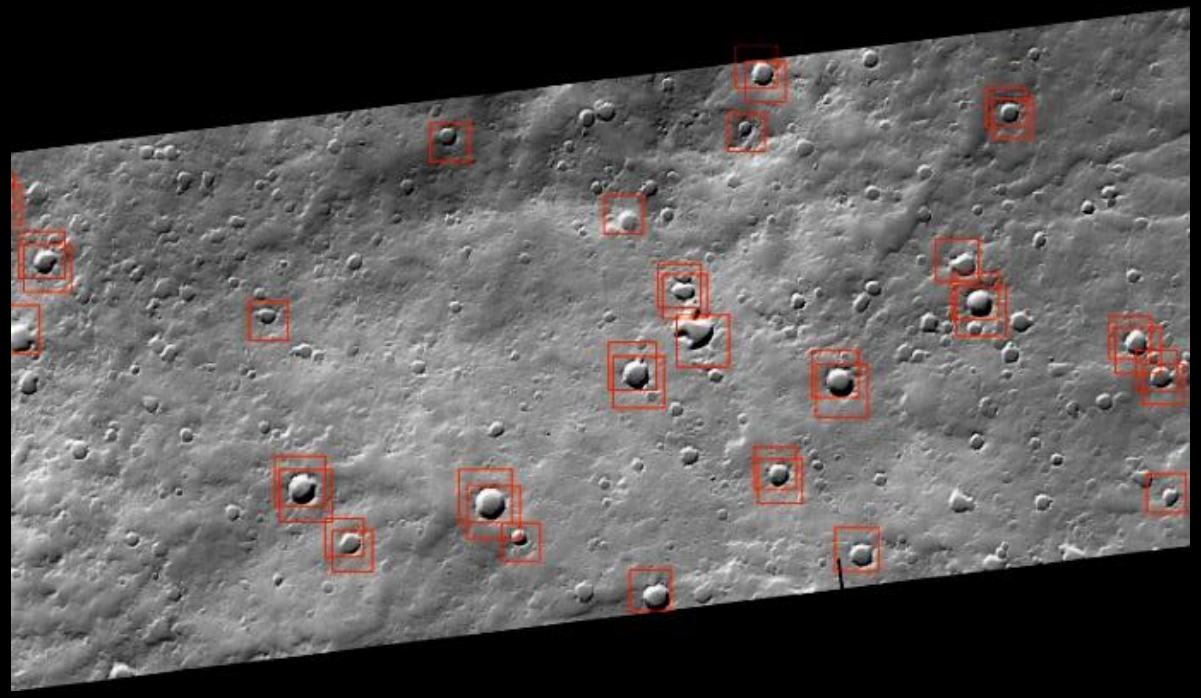
Roving Mars

Autonomy

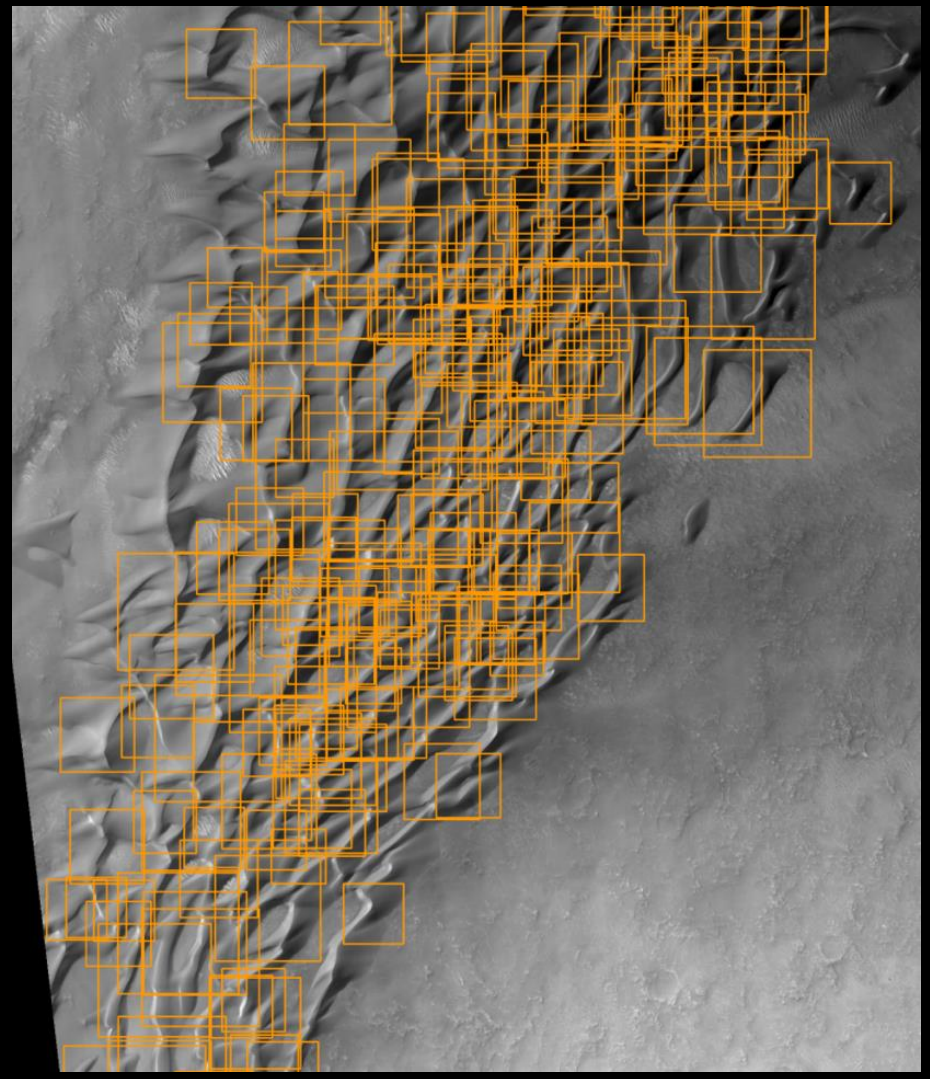
HiRISE - High Resolution Imaging Science Experiment
1.2M+ amazing views of MARS

= 13 – 24 min

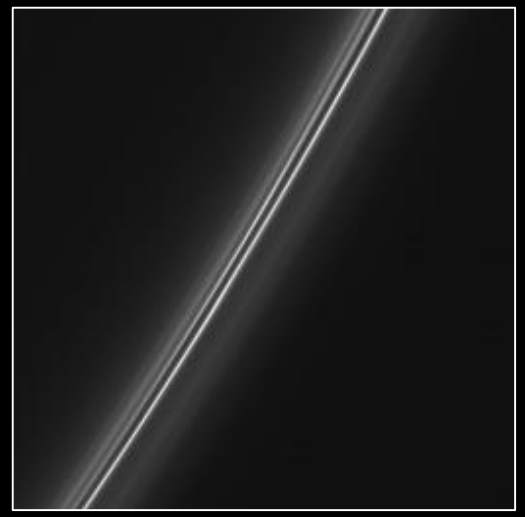
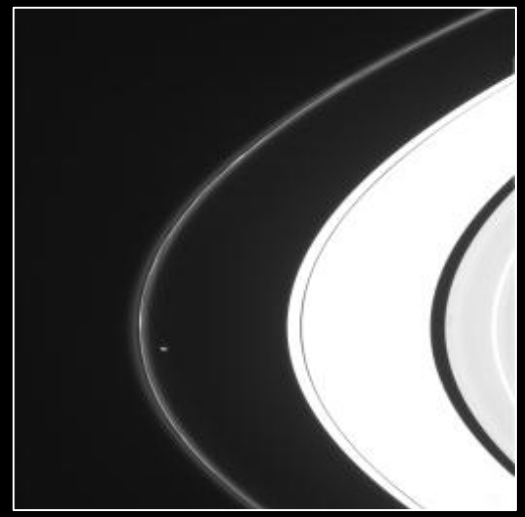
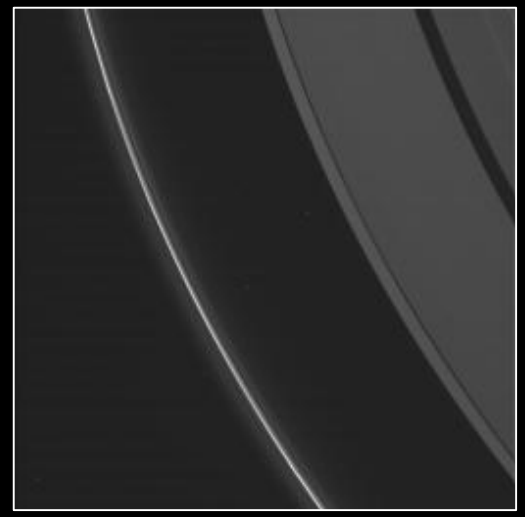
Landmarks are now searchable in M's of images



Deep Neural Networks
for landmark classification



http://pds-imaging.jpl.nasa.gov/search/

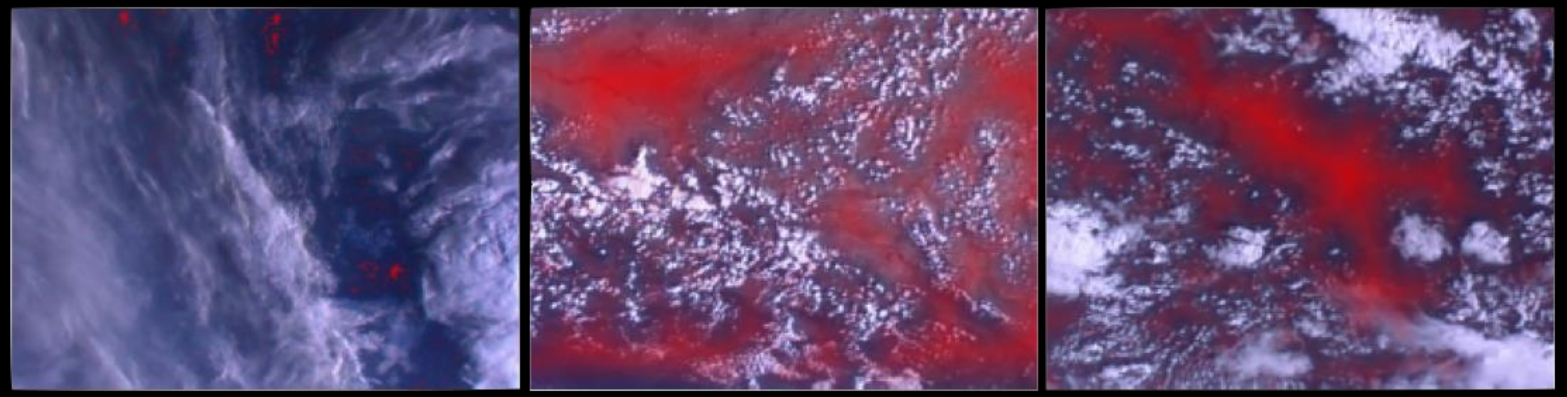




Searching Saturn's RINGS in 29M PDS images

A. Stanboli, B. Bue, K. L. Wagstaff, A. Altinok
Based on ImageNet, Krizhevsky et al., 2012

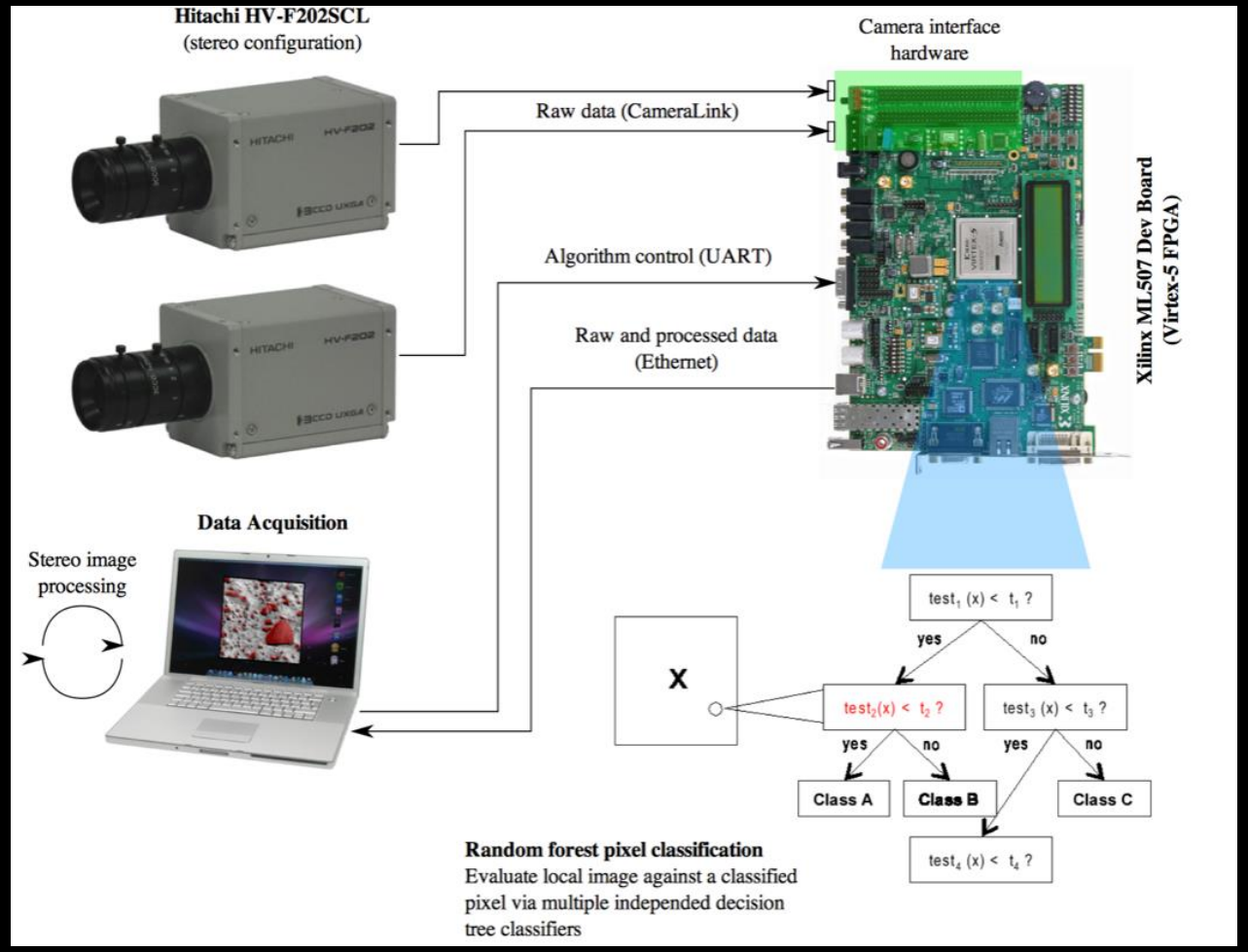
TextureCam Cloud Screening and Re-targeting – IPEX CubeSat

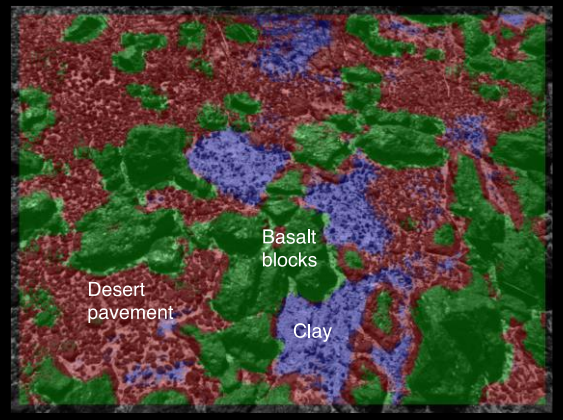
Random Decision Forests - Support Vector Machines



Real-Time Orbital Image Analysis Using Decision Forests, with a Deployment Onboard the IPEX Spacecraft
A. Altinok, D. R. Thompson, B. Bornstein, S. Chien, J. Doubleday, and J. Bellardo, Journal of Field Robotics, 2015

TextureCam Automated Image Classification





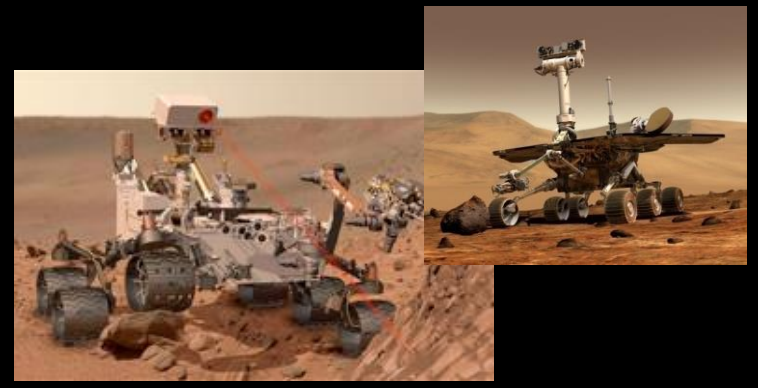
Cloud Filtering and Novelty Detection using Onboard Machine Learning for the EO-1 Spacecraft

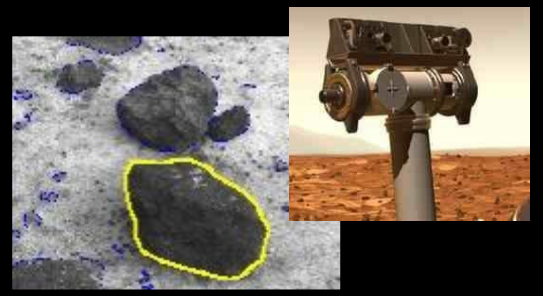
K. L. Wagstaff, A. Altinok, S. Chien, U. Rebbapragada, S. Schaffer, D. R. Thompson, and D. Tran. *IJCAI 2017 Workshop on AI*

AEGIS Autonomous Exploration for Gathering Increased Science

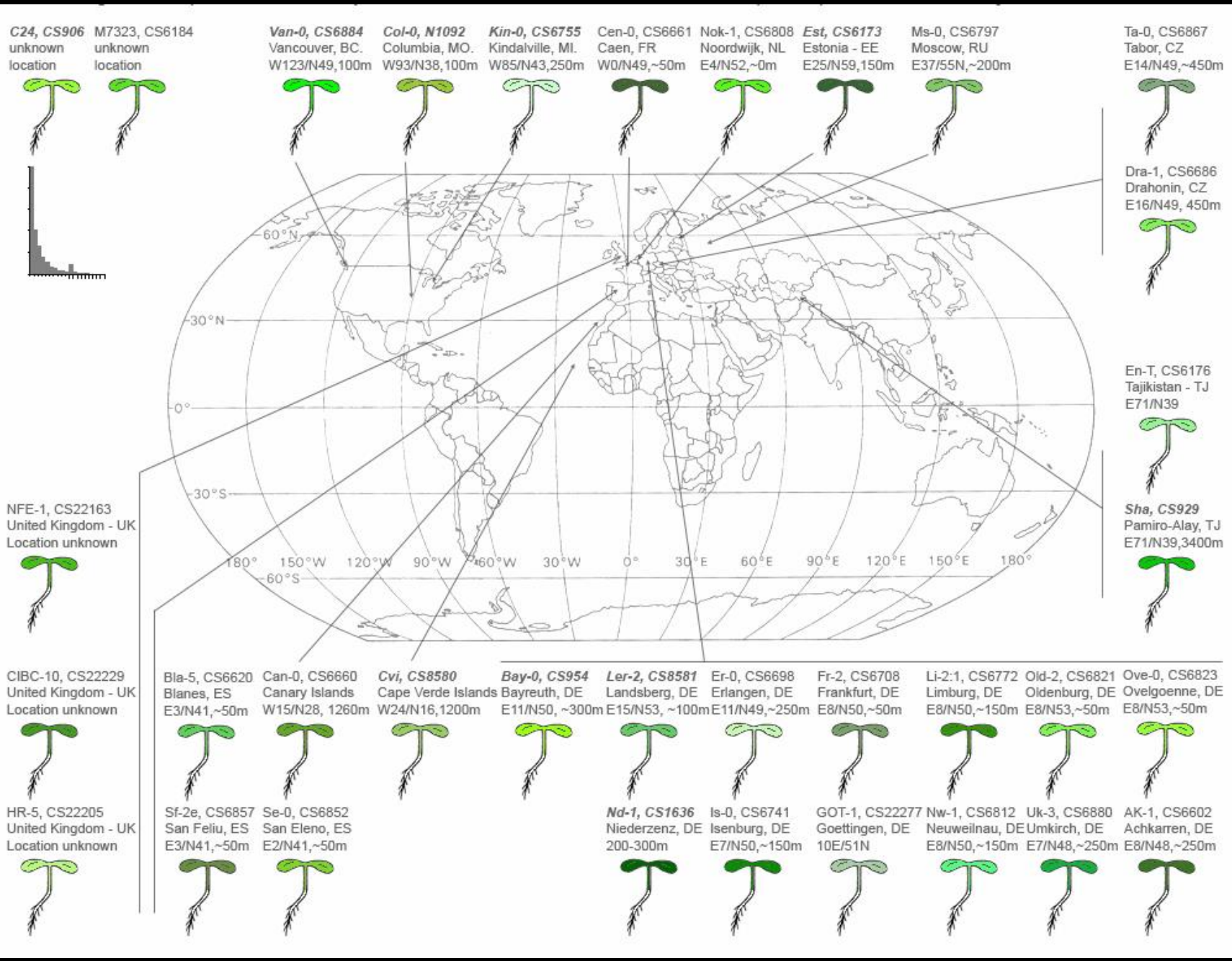
- Operational onboard Mars Exploration Rover (MER – Opportunity) and Mars Science Lab (MSL – Curiosity)

- Intelligent targeting and data acquisition capabilities
  - Identify rock targets onboard
  - Guided by scientist specified criteria
  - Can be run at end of drive or mid drive
  - No communication with ground required





AEGIS Automated Targeting for the MER Opportunity Rover
T. Estlin, B. Bornstein, D. Gaines, R. C. Anderson, D. Thompson, M. Burl, R. Castano, and M. Judd. ACM Transactions on Intelligent Systems and Technology, 3(3), 2012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location
M7323, CS6184
unknown
location
Van-0, CS6884
Vancouver, BC.
W123/N49,100m
Col-0, N1092
Columbia, MO.
W93/N38,100m
Kin-0, CS6755
Kindalville, MI.
W85/N43,250m
Cen-0, CS6661
Caen, FR
W0/N49,~50m
Nok-1, CS6808
Noordwijk, NL
E4/N52,~0m
Est, CS6173
Estonia - EE
E25/N59,150m
Ms-0, CS6797
Moscow, RU
E37/55N,~200m
Ta-0, CS6867
Tabor, CZ
E14/N49,~450m
Dra-1, CS6686
Drahonin, CZ
E16/N49, 450m
En-T, CS6176
Tajikistan - TJ
E71/N39
Sha, CS929
Pamiro-Alay, TJ
E71/N39,3400m
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30°N
0°
30°S
60°S
180°
150°W
120°W
90°W
60°W
30°W
0°
30°E
60°E
90°E
120°E
150°E
180°
NFE-1, CS22163
United Kingdom - UK
Location unknown
CIBC-10, CS22229
United Kingdom - UK
Location unknown
HR-5, CS22205
United Kingdom - UK
Location unknown
Bla-5, CS6620
Blanes, ES
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Can-0, CS6660
Canary Islands
W15/N28, 1260m
Cvi, CS8580
Cape Verde Islands
W24/N16,1200m
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Bayreuth, DE
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Ler-2, CS8581
Landsberg, DE
E15/N53, ~100m
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Erlangen, DE
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Frankfurt, DE
E8/N50,~50m
Li-2:1, CS6772
Limburg, DE
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Oldenburg, DE
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Ovelgoenne, DE
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Sf-2e, CS6857
San Feliu, ES
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Se-0, CS6852
San Eleno, ES
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Niederzenz, DE
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Is-0, CS6741
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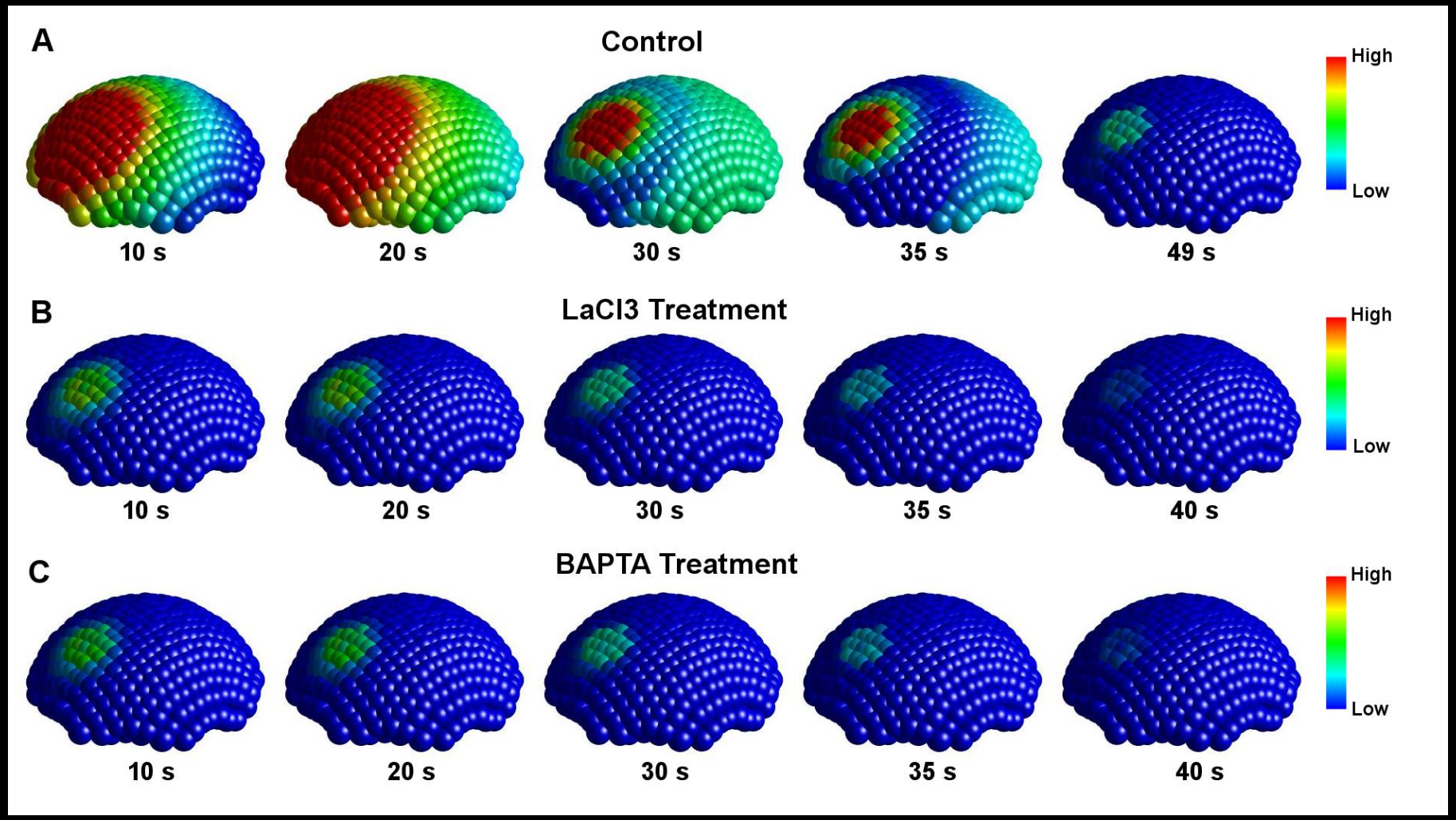
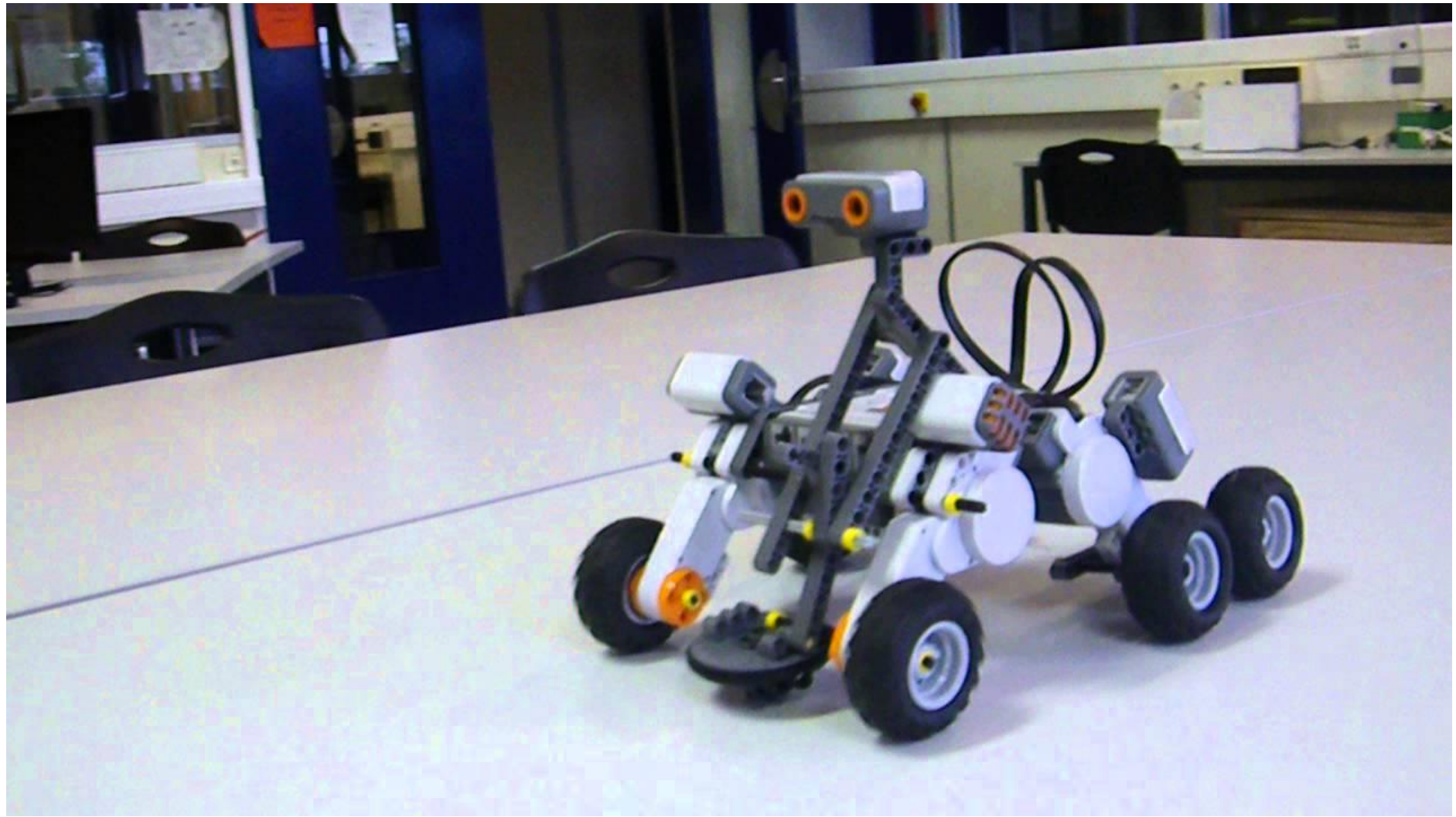
EXIT
STBD
NOD 2


A
Control
High
Low
10 s
20 s
30 s
35 s
49 s
B
LaCl3 Treatment
High
Low
10 s
20 s
30 s
35 s
40 s
C
BAPTA Treatment
High
Low
10 s
20 s
30 s
35 s
40 s

Curiosity

Math



https://www.jpl.nasa.gov/edu/